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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

HYDRODYNAMIC INVESTIGATION OF A $\frac{1}{13}$-SCALE MODEL OF

THE CONSOLIDATED VULTEE SKATE 7 SEAPLANE

EQUIPPED WITH TWIN HYDRO-SKIS

TED NO. NACA DE 342

By Robert E. McKann, Claude W. Coffee
and Donald D. Arabian

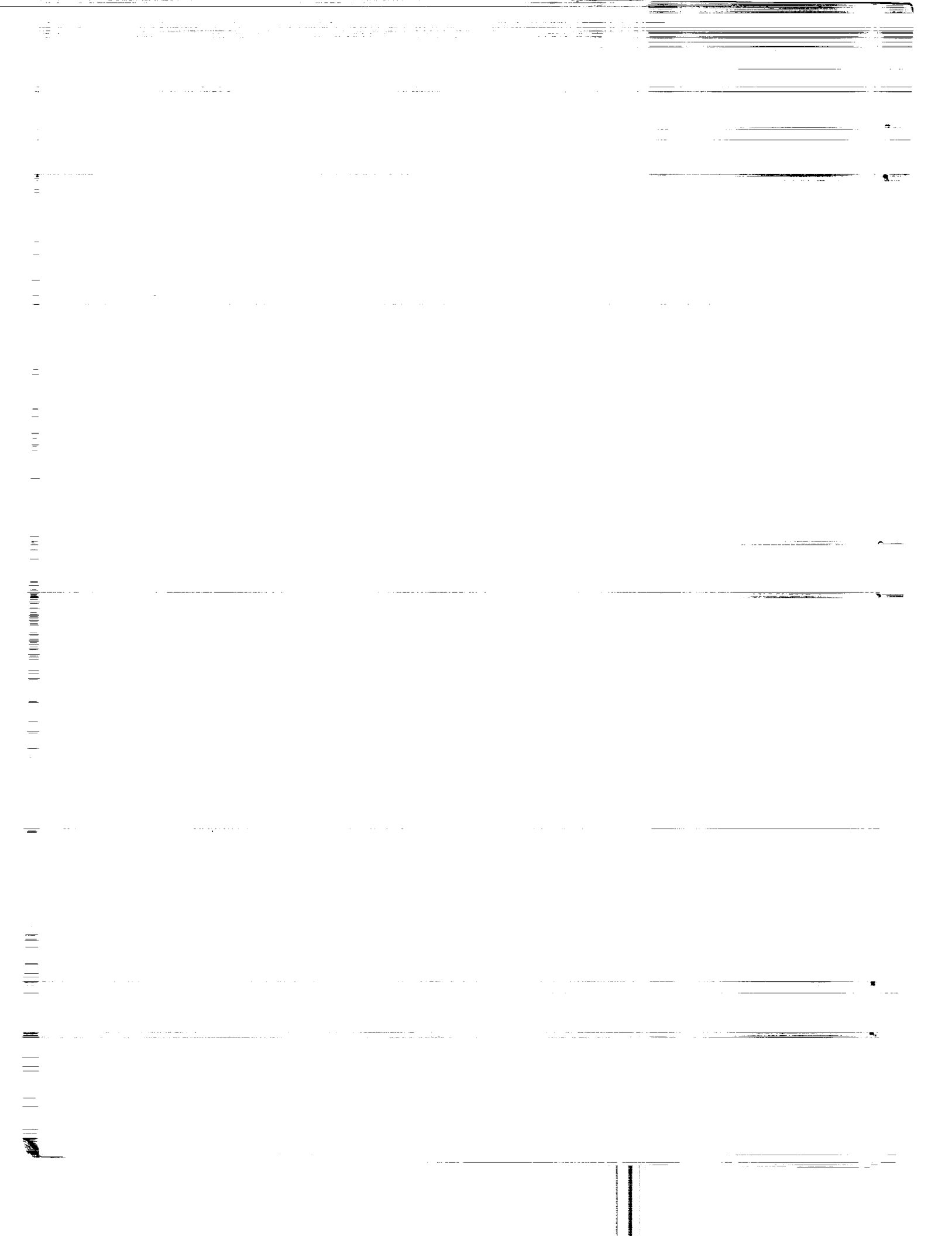Langley Aeronautical Laboratory
Langley Field, Va.

CLASSIFIED DOCUMENT

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

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SUMMARY

An investigation was made in Langley tank no. 2 to determine the hydrodynamic characteristics of the Consolidated Vultee Skate 7 seaplane equipped with twin hydro-skis suitable for use on either water or snow. Lower-limit porpoising occurred after emergence of the hydro-skis and was similar to that obtained with conventional hulls. No upper-limit porpoising was encountered. Stable take-offs in smooth water could be made at center-of-gravity locations aft of 20 percent mean aerodynamic chord. Spray entered the jet inlets at the low speeds and again upon hydro-ski emergence. The inboard flaps were wetted by spray throughout most of the take-off runs but the tail surfaces were clear of spray. No skipping occurred during smooth-water landings. The load-resistance ratio at the hump was 2.3. With estimated full-scale thrust, the calculated take-off time and distance was 21 seconds and 1620 feet, respectively.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, the National Advisory Committee for Aeronautics conducted a hydrodynamic investigation in Langley tank no. 2 on a model of the Consolidated Vultee Skate 7 seaplane equipped with hydro-skis. The Skate 7 is a jet-propelled transonic seaplane design with a gross

weight of 33,000 pounds, a wing loading of 34.4 pounds per square foot, and a weight-thrust ratio without afterburning of 2.2. After a large number of preliminary tests by Consolidated Vultee Aircraft Corporation and the NACA tank, a twin hydro-ski arrangement was chosen by the contractor that would be suitable for operation on water and snow, with consideration being given to weight and retraction, without change in the aerodynamic design and internal arrangement. This paper presents the hydrodynamic characteristics obtained with the final configuration adopted.

DESCRIPTION OF MODEL

The $\frac{1}{13}$-scale model of the Skate 7 seaplane used for these tests was constructed by Consolidated Vultee Aircraft Corporation. (See references 1 and 2.) Photographs of the model equipped with twin hydro-skis and designated Langley tank model 261-BN are shown as figure 1. The general arrangement and hull lines are presented in figures 2 and 3. Pertinent dimensions are given in table I. A drawing of the hydro-ski and strut is shown in figure 4. The design of the hydro-ski is explained in reference 1.

The basic Skate 7 seaplane design is unusual in that the hull height is considerably less than that used in conventional flying boats and the wing lower surface is faired into the hull bottom. Large fillets are used where the wing leading and trailing edges join the hull and the jet inlets are located in the leading-edge fillets. Retractable spray chines are provided from the bow aft to a retractable step.

For the present tests, hydro-ski and strut wells, and a fairing for the skis in their retracted position, were installed. No step was used but two small triangular-breaker strips with the thin edge forward were added to the afterbody of the model as shown in figure 2. The retractable spray chines were cut off 2 feet (full size) aft of the jet inlets. The model was provided with a range of elevator deflection from -15° to 5° and a range of center-of-gravity position from 10 to 30 percent mean aerodynamic chord $\bar{c}$.

The hydro-ski had a cross section which had been found acceptable for operation from snow during full-scale tests (reference 3). The hydro-ski thickness as well as the thickness and chord of the strut were determined from strength calculations by Consolidated Vultee Aircraft Corporation.

Jet thrust was simulated by supplying air from a reservoir on the towing carriage to ejectors, one in each throat of the twin jets. The hose carrying the air supply to the model jets were of gum rubber and were wound with fine wire spaced several diameters apart to maintain flexibility. An investigation of the decrement in trim amplitude during oscillation of the model in the air with the hose under the required pressure indicated that the restraint from the hose was small enough to be neglected in the tests.

APPARATUS AND PROCEDURE

Take-Off Stability

Smooth water.- The take-off stability was investigated using a towing gear for small models which was mounted in a gondola beneath the main carriage (fig. 5). Horizontal plywood plates were extended approximately 5 feet forward and 4 feet aft of the floor of the gondola to decrease the angularity of the air flow over the model. However, from runs made with the model free-to-trim just above the water's surface and with the hydro-skis and struts removed, a stabilizer deflection of -14° to the model base line was found necessary to match Consolidated Vultee aerodynamic data.

The model had freedom only in trim and rise. Trim was measured as the angle between the horizontal and the forebody keel at the step. Trims were read during constant-speed runs. Trim, rise, and speed were recorded against time on a recording oscillograph during accelerated runs. Front-quarter motion pictures were made with a motor-driven camera attached to a boom from the main carriage during accelerated runs. Speed lamp pictures were made during constant-speed runs.

The trim limits of longitudinal stability were investigated during constant-speed runs using full thrust. The model trim was slowly increased and decreased until the porpoising limit was crossed. Only the limits obtainable with the range of elevator deflection and center-of-gravity position available on the model were determined.

The variation of trim with speed for various positions of the center of gravity was determined during accelerated runs to take-off (approximately 5.5 ft/sec^2) with full thrust (15,000 lb, full size) and a range of fixed elevator deflection. The range of center-of-gravity position over which stable take-offs could be made with fixed elevator deflection was determined from the accelerated runs.

Rough water.- The take-off behavior in waves was investigated by using a gear attached beneath the main towing carriage, that allowed

the model approximately 4 feet of fore-and-aft movement as well as
freedom in rise and trim. (See fig. 6.) A stabilizer setting of -9°
was used with this gear. Fixed elevator take-offs were made in
4.5-foot waves 243 feet and 324 feet in length (full size), by using
sufficient thrust to render the model self-propelled. Two center-of-
gravity locations were investigated by using a rate of acceleration
of approximately 5.5 feet per second per second. The effect of a slower
rate of acceleration (1 ft/sec²) to the speed at which hydro-skis emerged
was also investigated.

Front-quarter motion pictures were taken. Rise, trim, vertical
acceleration, and carriage speed were recorded against time on an oscil-
lograph. A 12g strain-gage-type Statham electrical accelerometer mounted
on the towing staff was used to record the vertical accelerations of the
model. The natural frequencies of the 12g Statham accelerometer and the
recording galvanometer was 325 and 150 cycles per second, respectively.
Both were damped to approximately 0.65 of their critical values. The
accelerometer and galvanometer had approximately flat frequency response
curves to 180 and 100 cycles per second, respectively. In the static
condition, all accelerometers were considered to read zero.

Landing Stability

Smooth water.- The model was launched from the monorail catapulting
gear for smooth-water landings (fig. 7). A stabilizer setting of
-9° was used. Landings were made at contact trims ranging from 3°
to 20°. A constant launching clearance above the water, corresponding
to approximately 2.2 feet (full size) and a rate of descent of approx-
imately 200 to 300 feet per minute (full size) at contact, was main-
tained. The center of gravity was located at $0.20\bar{c}$ and the flaps were
deflected 20°. The model was launched as a free body at a speed
slightly greater than flying speed and glided onto the water in simu-
lation of power-off landings. Motion pictures of the landings were
made with a camera stationed at the side of the tank.

Rough water.- Rough-water landings were made from a launching
gear attached to the rear of the main towing carriage (fig. 8). The
model was launched and landed at a trim of 8° in oncoming waves gen-
erated by a wave maker. A launching clearance of 2.2 feet (full size)
was maintained above the wave crests. The flaps were deflected 20°,
the center of gravity was located at $0.20\bar{c}$, and the stabilizer setting
was -9°.

The waves were 4.5 feet in height and 93 to 311 feet in length
(full size). The variation with wave length of the maximum normal
accelerations was determined with a single-component mechanical

accelerometer. A 20g strain-gage-type accelerometer was then used to determine the maximum normal acceleration at the critical wave length.

The 20g accelerometer had a natural frequency of 200 cycles per second and was damped to approximately 0.65 of its critical value; its frequency response curve was essentially flat to 120 cycles per second. A trailing wire from the model to the main carriage was used to transmit the signals of the accelerometer. To minimize the effect of the trailing wire on the model behavior after launching, the carriage was decelerated with the model. Check runs were made to insure that the effect of the trailing wire on the motions of the model was negligible. Model motions during landings were recorded by a motion-picture camera.

Resistance

The resistance tests were made with the small-model gondola attached to the main towing carriage (fig. 5). A stabilizer setting of -14° was used. The free-to-trim resistance of the complete model was measured in smooth water during constant-speed runs for three fixed elevator deflections with the center of gravity at 0.20c̄ and with full thrust (static thrust, 15,000 lb, full size). At the contractor's request, zero flap deflection was used up to slightly after hydro-ski emergence speed (40.6 knots, full size) and from this speed to take-off the flaps were set at 20°.

The effective thrust of the model jets was measured at constant speeds, with the model in the air, by measuring the force on the model and its supporting gear with full thrust applied and by adding to this measurement the drag of the model and its supporting gear, similarly measured in runs without thrust applied. The air drag of the towing gear was determined with the model removed. The effective thrust was greater than the total resistance of the model and gear throughout these tests. Thus, the resistance of the model, including its air drag, was obtained by subtracting the balance reading and the air drag of the towing gear from the effective jet thrust.

The loads on the water for the trims and speeds of the resistance tests were obtained from a lift curve that was determined from the variation in take-off speeds with trim observed in the take-off stability tests. Rise was measured at the center of gravity with zero rise being considered as the position of the center of gravity when the forebody keel touched the water surface at zero trim.

RESULTS AND DISCUSSION

All data presented have been converted to full-scale values.

Take-Off Stability

Smooth water.- In figure 9, the lower trim limit of stability is shown. No upper trim limit of stability was encountered. Lower-limit instability occurred only after emergence of the hydro-skis. The lower trim limit was generally similar to that found with conventional hulls.

In figure 10, trim is plotted against speed for various elevator deflections at four locations of the center of gravity. At the forward location of the center of gravity, emergence of the hydro-skis was delayed because of the low trim and occurred in the region of lower-limit porpoising. At the after locations of the center of gravity, the hydro-skis emerged prior to lower-limit porpoising but there was a tendency for the model to oscillate in trim before attaining a stable condition. Although the amplitude of this trim oscillation was as great as 2°, the oscillation frequency was low compared with the porpoising frequency; a mild motion resulted which was not considered as an operating limit.

A plot of elevator deflection against center-of-gravity location at which the maximum amplitude of porpoising was 2° is presented in figure 11. In all cases this center-of-gravity limit of stability was imposed by lower-limit porpoising and no aft center-of-gravity limit was encountered. Stable take-offs could not be made at center-of-gravity locations forward of approximately $0.20\bar{c}$.

A more forward hydrodynamic center-of-gravity limit than that shown in figure 11 would be desirable to permit stable take-offs with the full range of fixed elevator deflections throughout the aerodynamic-center-of-gravity range ($0.22\bar{c}$ to $0.24\bar{c}$). A more forward location of the hydro-skis relative to the center of gravity of the seaplane would tend to move the hydrodynamic center-of-gravity limit forward. From unpublished data, forward movement of the hydro-skis might also be expected to decrease the hump resistance but increase the maximum normal accelerations during rough-water landings.

Rough water.- Time histories of four typical take-offs made in rough water are presented in figure 12. Rise, trim, speed, and vertical acceleration are plotted against time. It is noted from figures 12(a) and 12(b) that the magnitudes of the trim and rise oscillations were larger at the longer wave length. They were also greater with the center of gravity located at $0.30\bar{c}$ (fig. 12(c)) than at $0.20\bar{c}$ (fig. 12(a)). The use of a slow rate of acceleration to emergence speed (fig. 12(d)) instead of a fast rate for the entire take-off (fig. 12(a)) made little change in the magnitude of the trim oscillations and vertical accelerations but increased the magnitude of the rise oscillations. The frequency of the rise and trim oscillations was not greatly changed but more oscillations occurred with the slow rate of acceleration.

Landing Stability

Smooth water.- No skipping occurred over the range of contact trim
investigated (3° to 20°) in smooth-water landing tests. Some trim
oscillation occurred in the latter part of the runout during landings
made at low contact trims. The model trimmed down about the sternpost
after contact at high trims and oscillated several times before reaching
a steady trim, but the hydro-skis did not leave the water.

Rough water.- The values of maximum normal acceleration obtained
during landings at the critical wave length of 150 feet with the use
of the Statham accelerometer are presented in table II. The maximum
normal acceleration measured was 8g. It should be noted that this
value is not directly comparable to the attenuated values obtained for
the basic Skate model (reference 4) with a low-frequency mechanical
accelerometer but is comparable to an unattenuated value of 12.8g
obtained from unpublished data on tank tests of the basic Skate model.

Spray Characteristics

Speed-lamp pictures made during constant-speed runs are presented
as figure 13. Approximate full-scale jet thrust and mass inflow were
simulated. At 10.7 knots, spray from the bow rode over the spray dams
and was sucked into the jet inlets (fig. 13(b)). The inboard flaps
were heavily wetted by forebody spray at 21.4 knots (fig. 13(c)) but
were clear again at 32.1 knots (fig. 13(d)). At emergence of the
hydro-skis (fig. 13(e)) a heavy burst of spray from the leading edge
of the hydro-skis wetted the wing and the inboard flaps and entered
the jet inlets. As speed was increased, the inboard flaps continued
to be wetted by spray from the hydro-skis (fig. 13(f)). The afterbody
was generally clear of solid water over the speed range from 64 knots
to take-off, but was heavily wetted by spray from the hydro-skis as
shown in figures 13(g), 13(h), and 13(j). The short wetted length of
the hydro-skis and the low trim associated with the take-off condition
are illustrated in figure 13(j). The horizontal tail was clear of
spray throughout the take-off.

Resistance

The minimum stable resistance in the trim range obtainable by use
of the elevators, load on the water, and model thrust is plotted against
speed in figure 14. The corresponding trim and rise values are shown
in figure 15. The model thrust decreased 15 percent during the take-
off run while a decrease of 3 percent was estimated for the full-size
jet engine. The maximum resistance occurred prior to the emergence
of the hydro-skis and the load-resistance ratio at the hump was 2.3.

The hydro-skis, struts, and wells are believed to contribute greatly to the high hump resistance. Beyond the hump, the resistance decreased rapidly with speed but heavy afterbody wetting is believed to contribute considerably to the resistance at high speeds. With the estimated full-scale thrust, the corresponding take-off time and distance was calculated to be 21 seconds and 1620 feet.

CONCLUSIONS

The results of the hydrodynamic investigation of the model of the Consolidated Vultee Skate 7 seaplane equipped with twin hydro-skis for operation from water and snow indicated that:

1. A lower trim limit of stability generally similar to that found with conventional hulls was found after emergence of the hydro-skis. No upper-limit porpoising was encountered.

2. Stable take-offs in smooth water could be made with the center of gravity located aft of 0.20 percent mean aerodynamic chord.

3. Spray entered the jet inlets at low speed and again upon emergence of the hydro-skis. Spray wetted the inboard wing flaps throughout most of the take-off run. No spray struck the tail surfaces during take-off.

4. No skipping occurred during smooth-water landings over a range of contact trim from 3° to 20°.

5. Maximum resistance occurred prior to emergence and the load-resistance ratio at the hump was 2.3. With estimated full-scale thrust, the calculated take-off time and distance was 21 seconds and 1620 feet.

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1. Caldwell, R. W.: Data and Specifications for a 1/13 Scale Powered
      Tank Model of Skate 7. Rep. No. ZH-063, Consolidated Vultee
      Aircraft Corp., Jan. 20, 1949.

2. Caldwell, R. W.: Hydrodynamic Design of the Consolidated Vultee
      Seaplane Night Fighter. Rep. No. ZH-061, Consolidated Vultee
      Aircraft Corp., Dec. 1948.

3. Anon.: Summary Report on USAF Project MX-940. Rep. 2719,
      Edo. Corp., April 5, 1949.

4. McKann, Robert E., Coffee, Claude W., and Arabian, Donald D.:
      Smooth-Water Landing Stability and Rough-Water Landing and Take-Off
      Behavior of a $\frac{1}{13}$-Scale Model of the Consolidated Vultee Skate 7
      Seaplane - TED No. NACA DE 338. NACA RM SL9H31, Bur. Aero., 1949.

TABLE I

GENERAL DATA FOR LANGLEY TANK MODEL 261-BN

	Model	Full Size
Hull:		
Design gross load, lb	[a]14.88	33,000
Length of hull bottom, in.	64.6	840
Over-all length, in.	75.7	984
Angle of dead rise at step, deg	30	30
Angle of afterbody keel, deg	5.5	5.5
Height of center of gravity above		
base line, in.	4.46	58
Height of center line of jet		
inlet above base line, in.	6.01	78.12
Hydro-skis:		
Unit loading, lb/sq ft	50.8	660
Distance of hydro-ski trailing		
edge aft of hull bow, in.	37.1	481
Distance of hydro-ski keel below		
base line, in.	2.38	31
Angle of incidence, deg	2	2
Wing:		
Area, sq ft	5.69	960
Span, in.	57.2	744
Root chord, in.	20.4	266
Tip chord, in.	8.15	106
Mean aerodynamic chord, in.	15.2	197.8
Leading edge of mean aerodynamic		
chord aft of bow, in.	29.8	387.5
Aspect ratio	4	4
Sweepback at 25-percent-chord		
line, deg	35	35
Dihedral angle, deg	0	0

[a]Specific weight of Langley tank no. 2 water in these tests
    was 63.2 lb/cu ft.

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TABLE I

GENERAL DATA FOR LANGLEY TANK MODEL 261-BN - Concluded

	Model	Full Size
Horizontal tail:		
Total area projected, sq ft	0.85	144
Span, in.	22.15	288
Dihedral angle, deg	10	10
Vertical tail:		
Total area, sq ft	0.69	117
Power:		
Static thrust, lb	6.84	15,000

TABLE II

MAXIMUM NORMAL ACCELERATIONS OF LANGLEY TANK MODEL 261-BN

DURING LANDINGS IN WAVES 150 FEET LONG

Run number	Impact	Acceleration (g units)	Behavior at maximum impact
1	5	6.2	
2	9	3.7	Skis planed over wave crest
3	5	4.3	
4	1	6.3	Skis contacted wave trough and forebody contacted wave upslope
5	2	5.1	Skis and forebody contacted wave upslope
6	1	3.1	
7	3	3.6	
8	5	6.4	Skis and afterbody contacted wave upslope
9	7	4.5	
10	3	5.9	Afterbody contacted wave slope and trimmed model down into next wave
11	2	4.8	
12	4	6.1	Skis cut through wave crests and hull contacted water
13	7	5.5	Afterbody contacted wave crests, trimming model down during most of run
14	3	6.8	Afterbody contacted wave crests, trimming model down during most of run
15	4	5.8	
16	5	4.2	
17	2	7.1	Skis buried in wave upslope and forebody contacted
18	4	6.9	Skis and hull contacted wave
19	1	5.0	Skis and afterbody contacted wave
20	2	7.6	Skis contacted wave trough and forebody contacted wave upslope
21	4	8.0	Skis contacted wave trough and forebody contacted wave upslope
22	3	7.9	Afterbody contacted wave crest, trimming forebody into oncoming wave

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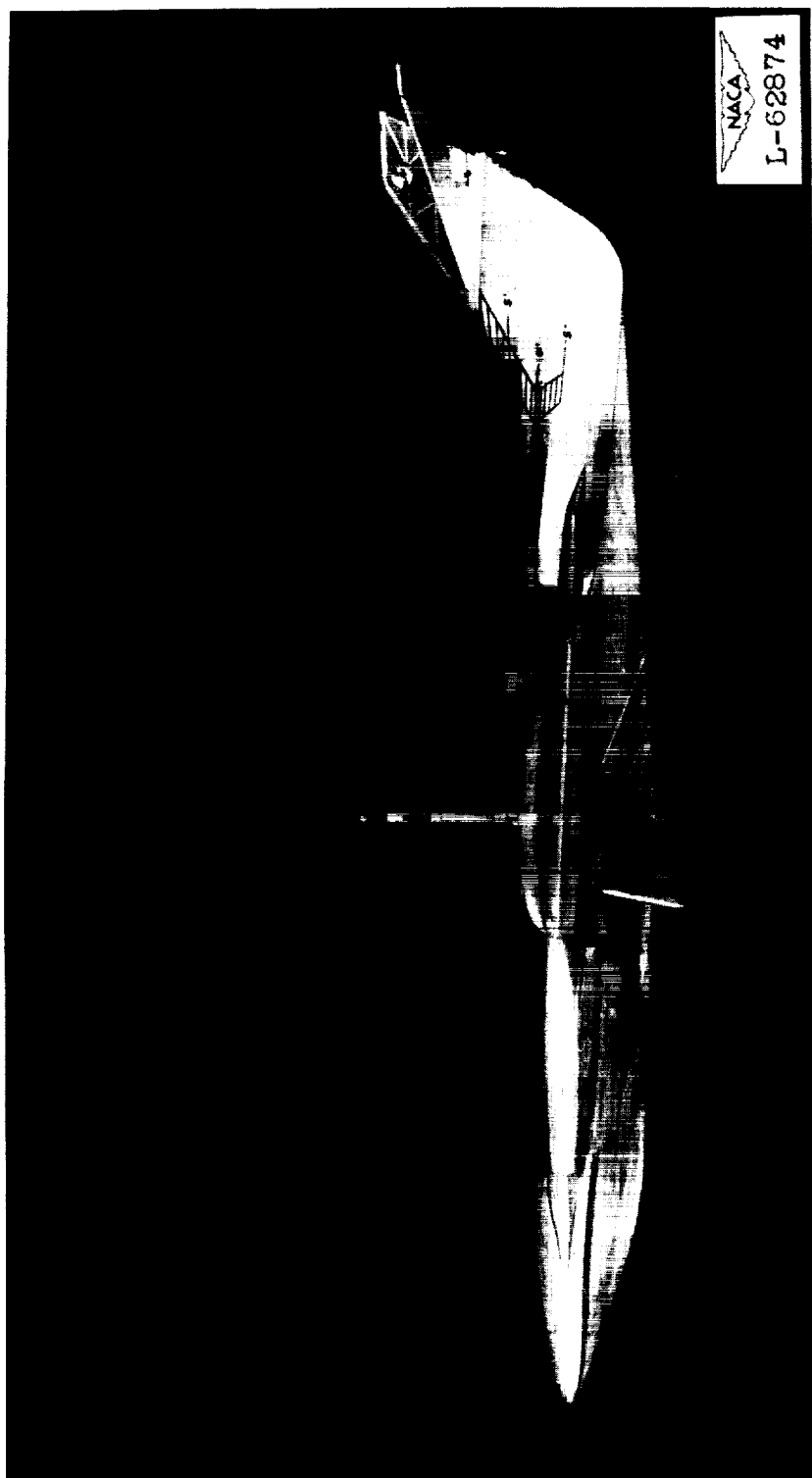
(a) Profile view.

Figure 1.- Langley tank model 261-BN.
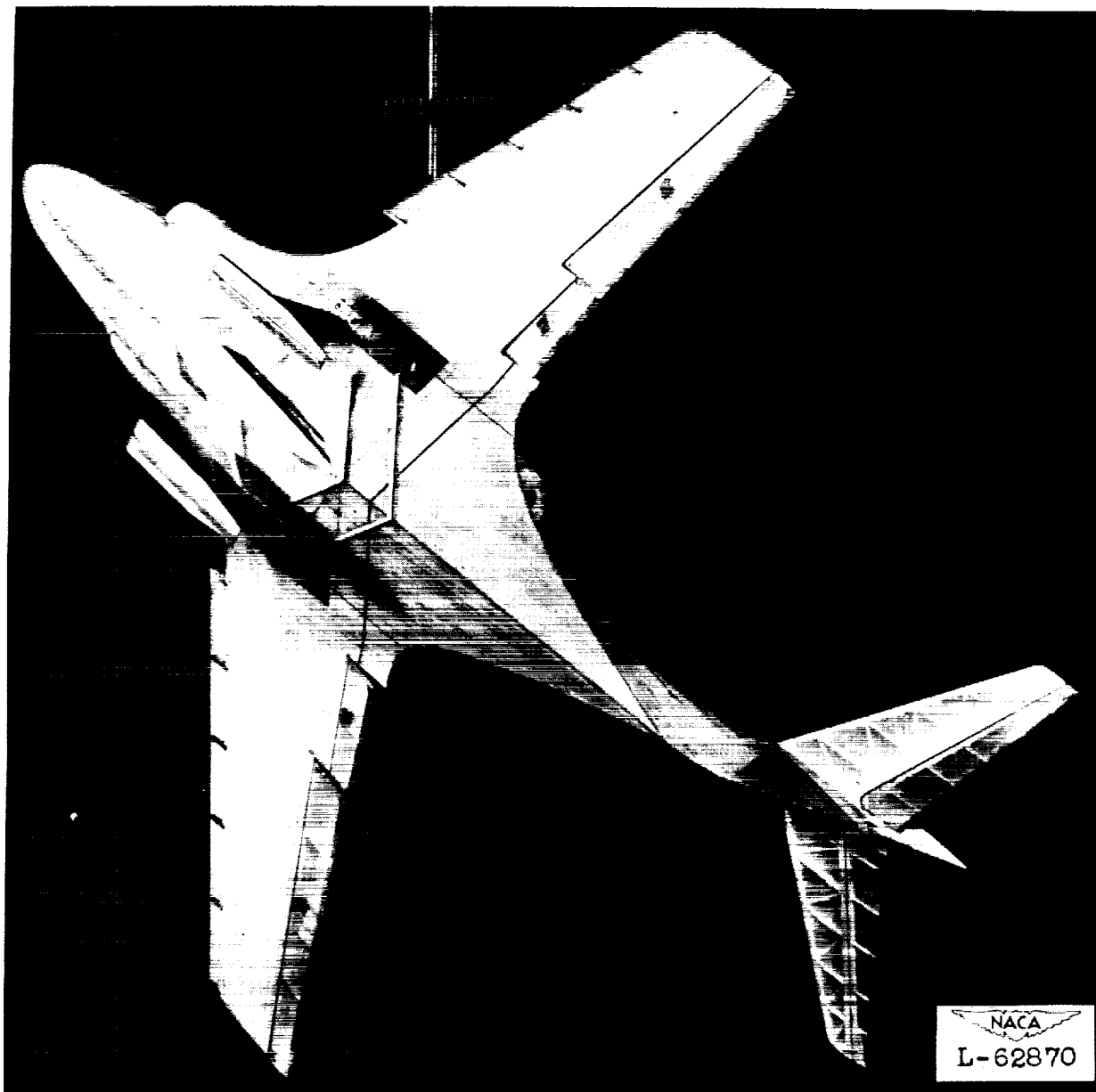
(b) Rear-quarter bottom view.

Figure 1.- Concluded.
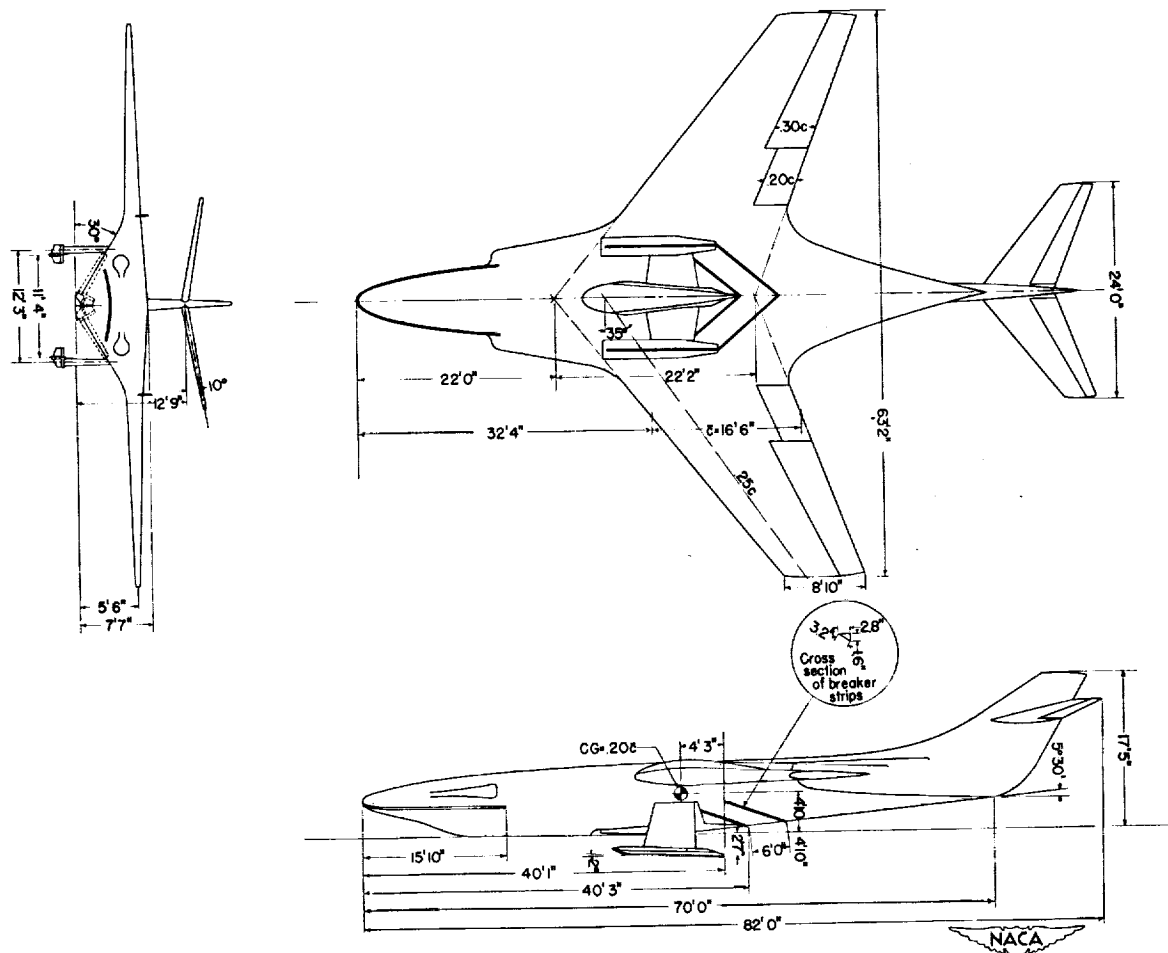
Figure 2.- General arrangement of Skate equipped with hydro-skis.
(All dimensions are full size.)

Bottom view

Sta ① ② ③ ④ ⑤ ⑥ ⑦
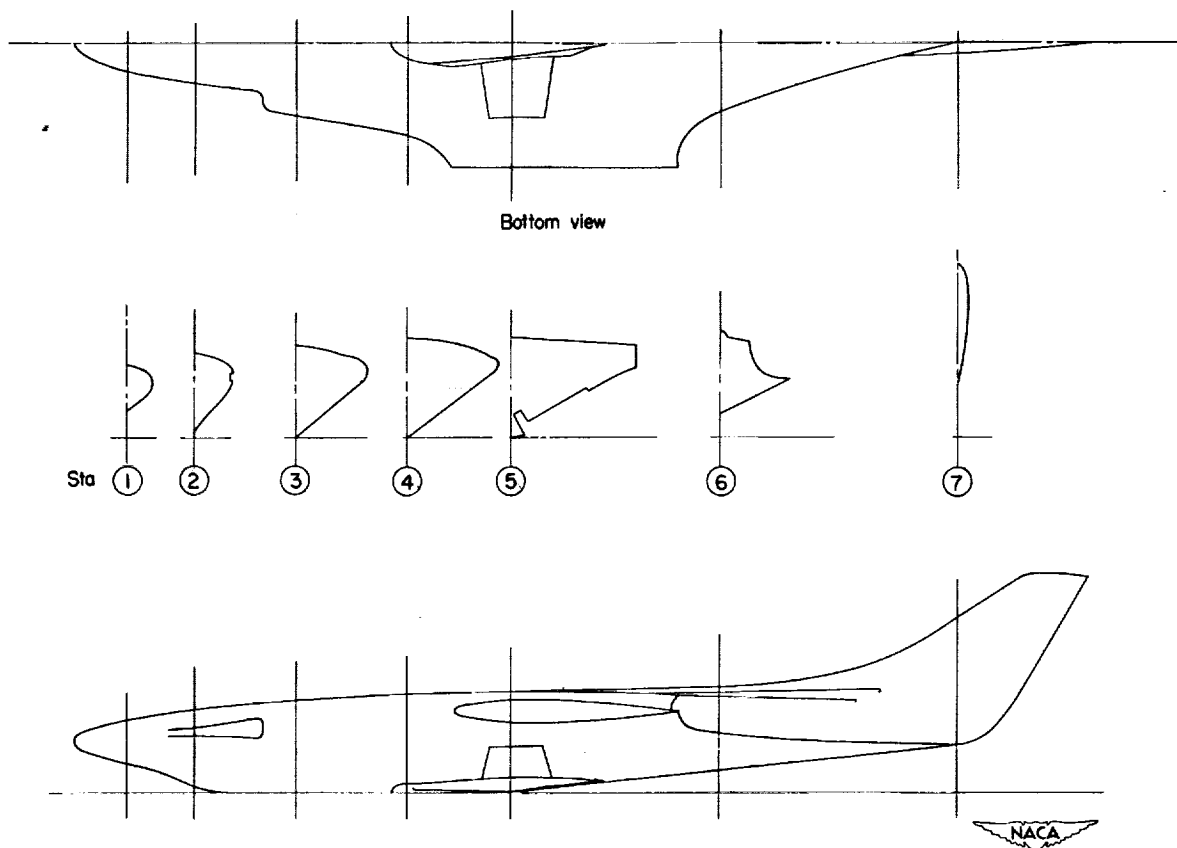
Figure 3.- Hull lines of Skate modified for hydro-skis.

SKI STRUT ORDINATES	
Station (percent c)	Half ordinate (percent c)
0	0
10	4.06
20	5.42
30	6.17
40	6.41
50	6.17
60	5.88
70	5.18
80	3.82
90	2.53
100	0
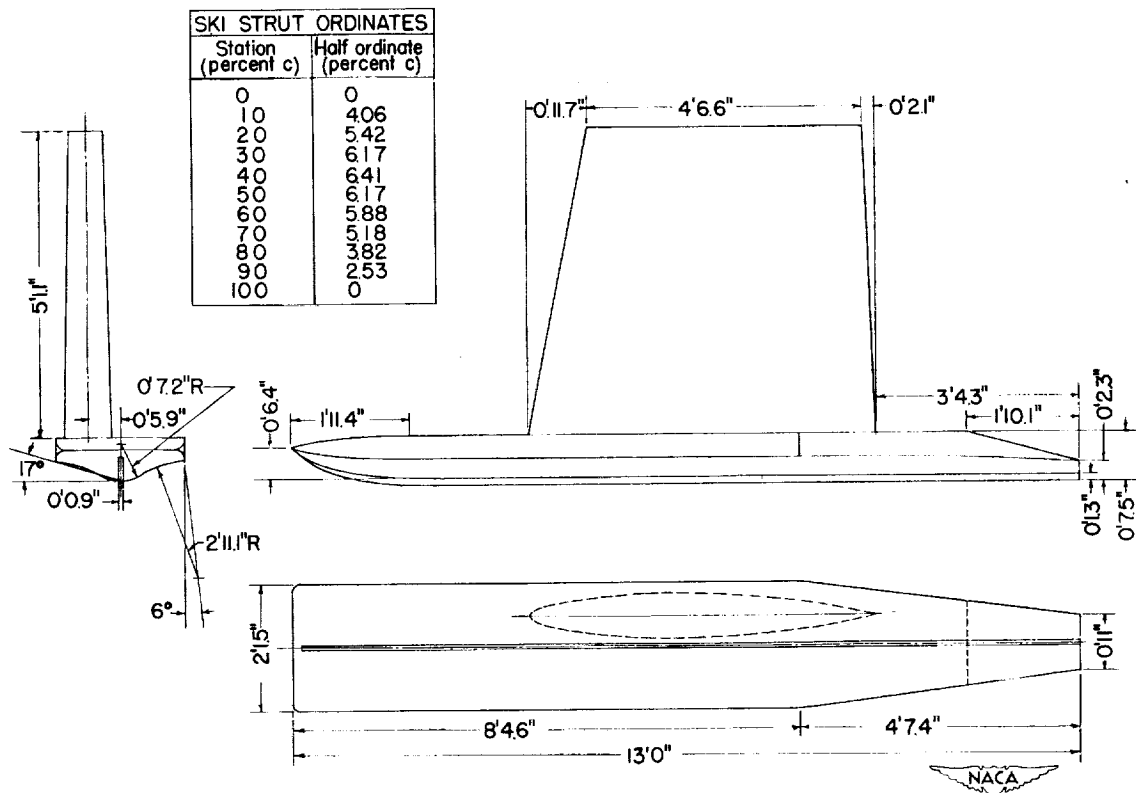
Figure 4.- Hydro-ski and strut arrangement.   (All dimensions are full size.)

Figure 5.- Setup of model on small-model gondola.
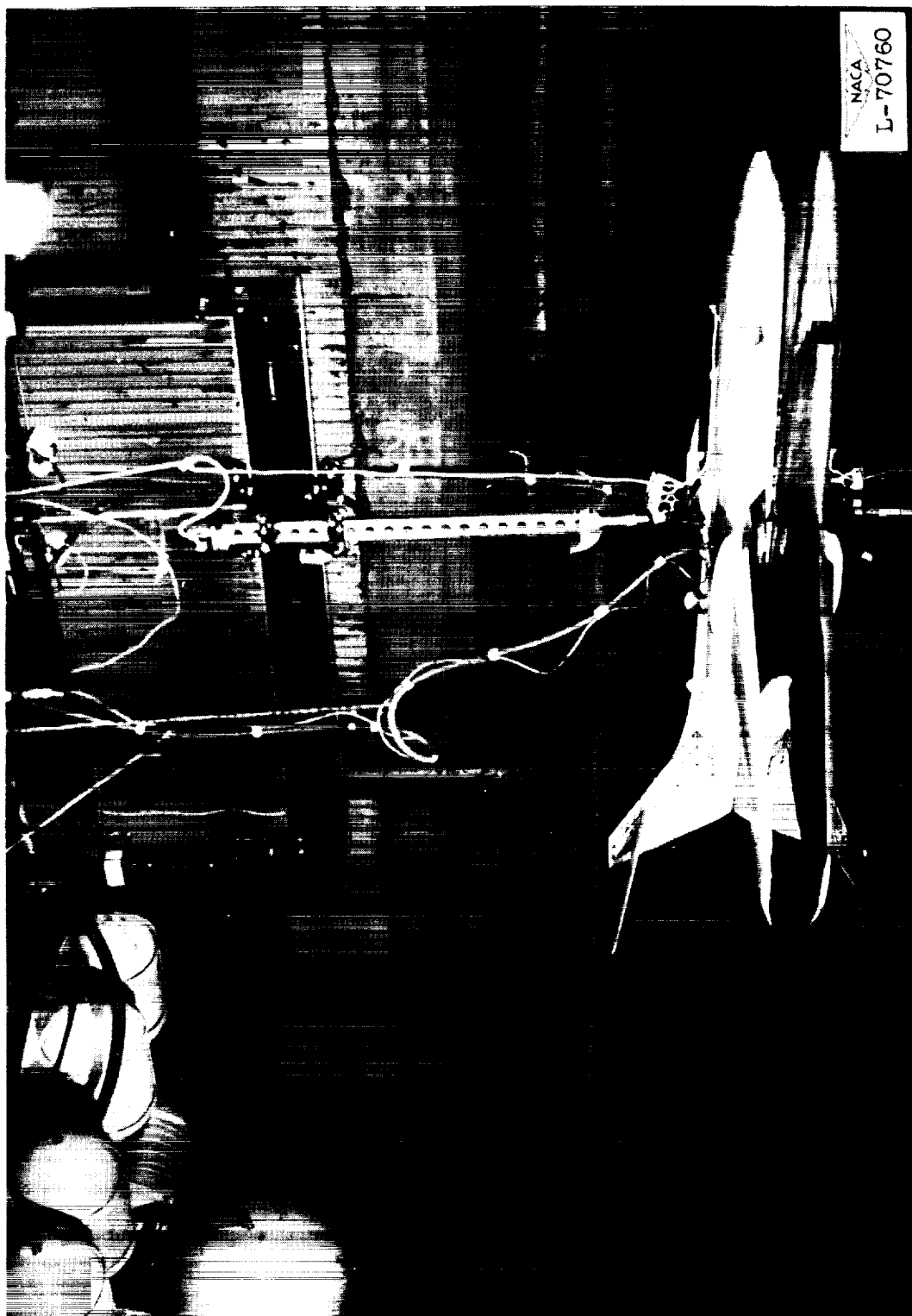
Figure 6.- Setup of model on fore-and-aft gear.
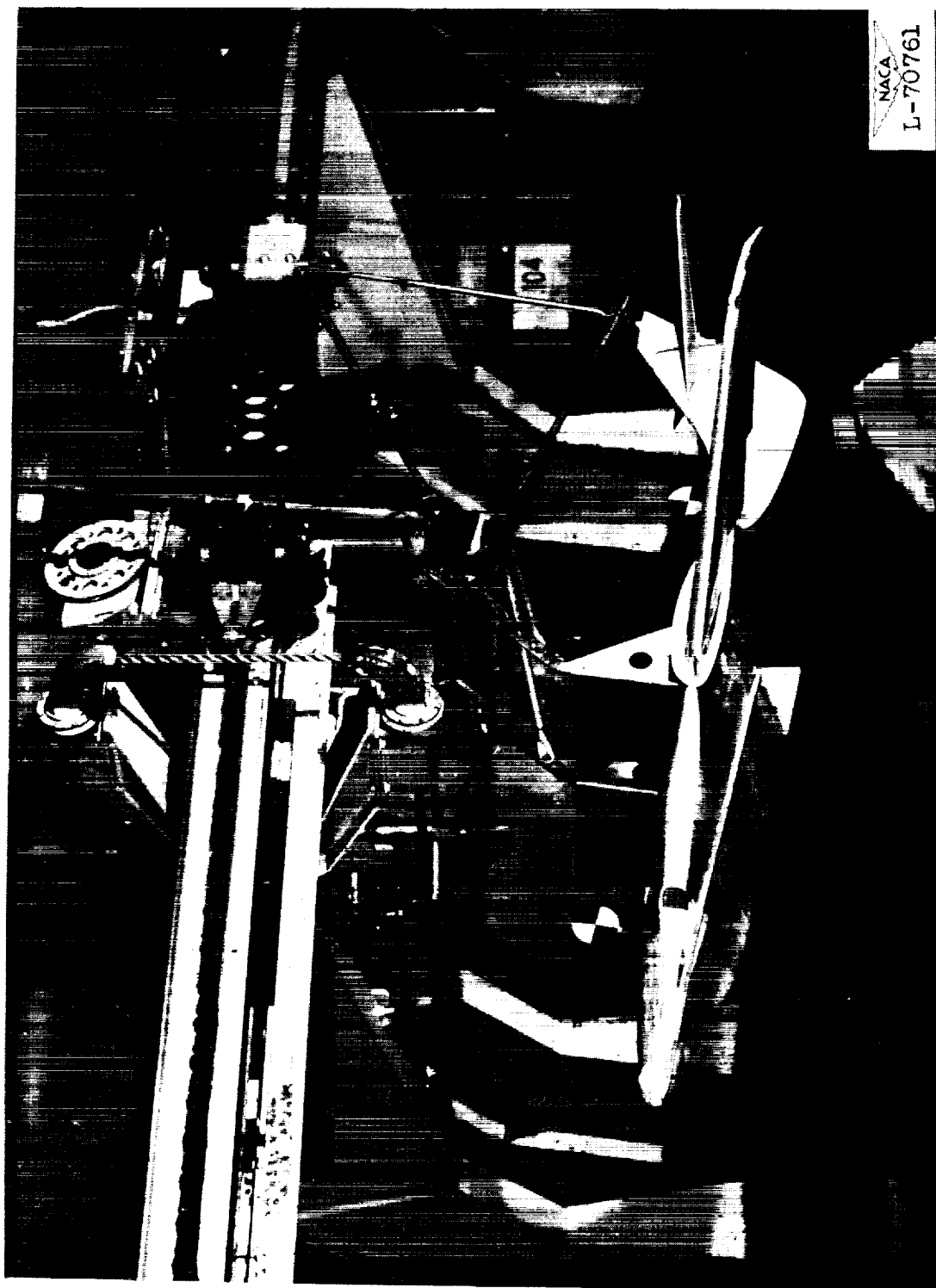
Figure 7.- Setup of a model on the monorail launching gear.

Figure 8.- Setup of a model on main-carriage launching gear. L-70762
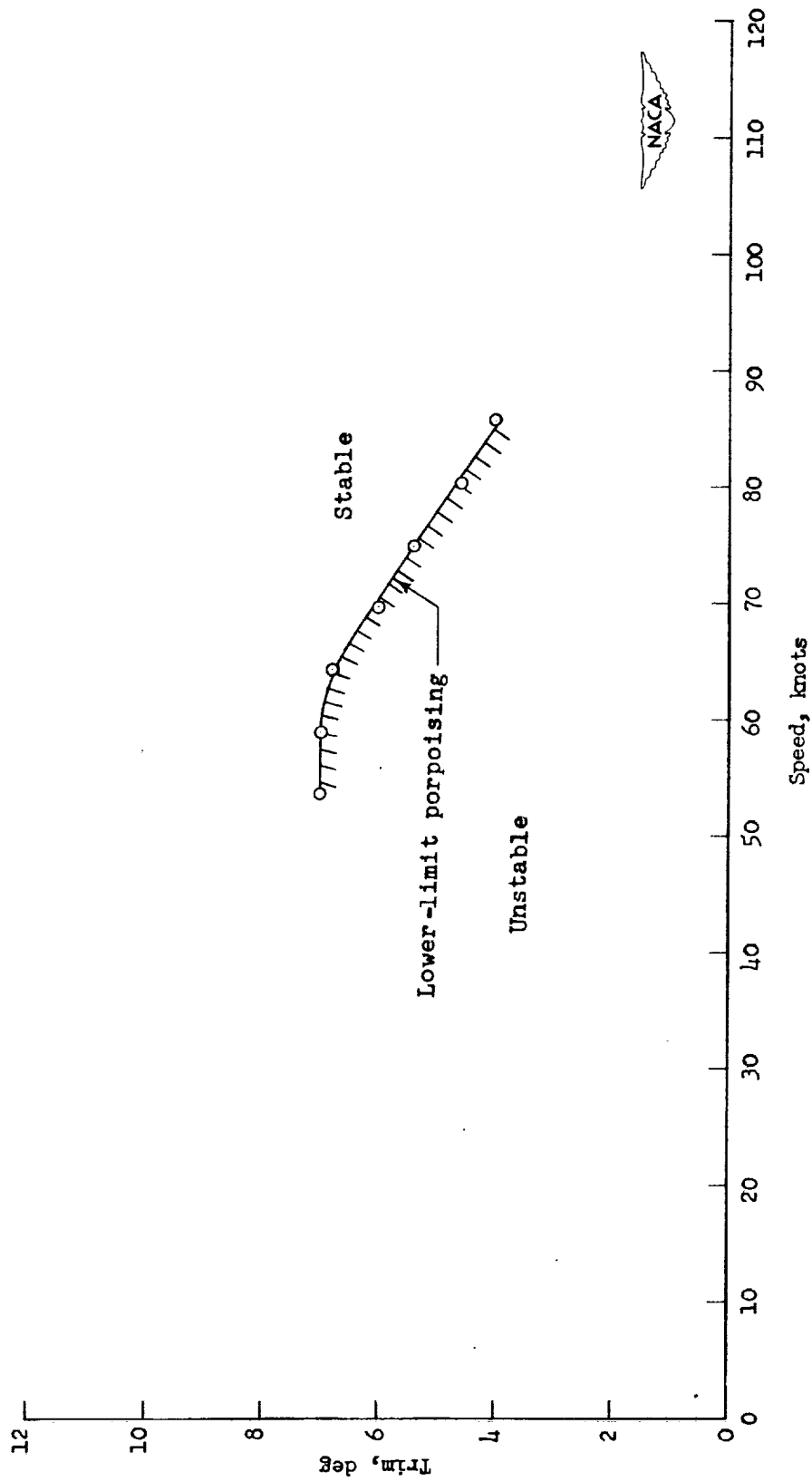
Figure 9.- Trim limits of stability. Gross load, 33,000 pounds;
flap deflection, 20°.
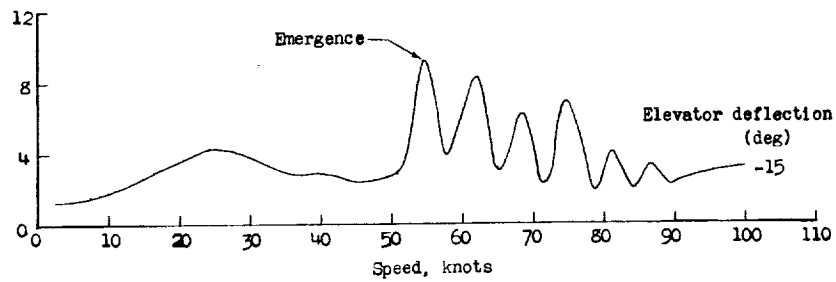
(a) Center-of-gravity location, 16 percent mean aerodynamic chord.
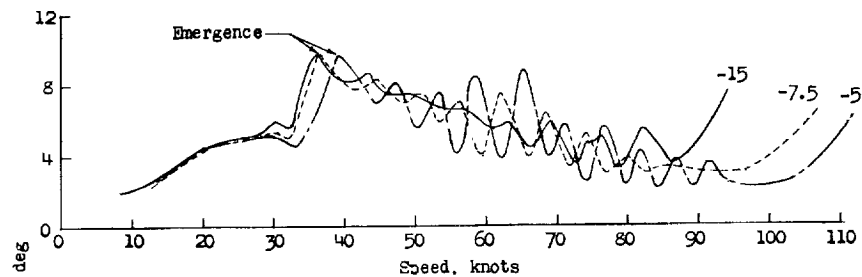
(b) Center-of-gravity location, 20 percent mean aerodynamic chord.
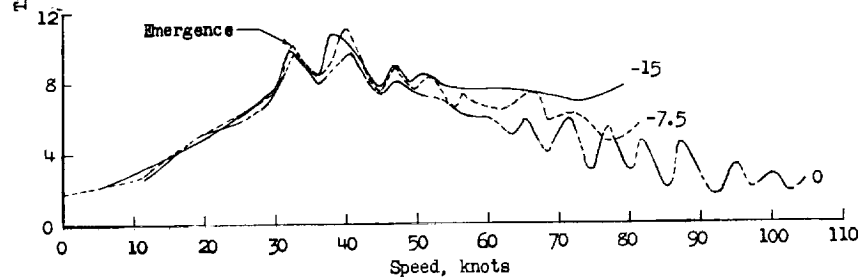
(c) Center-of-gravity location, 24 percent mean aerodynamic chord.
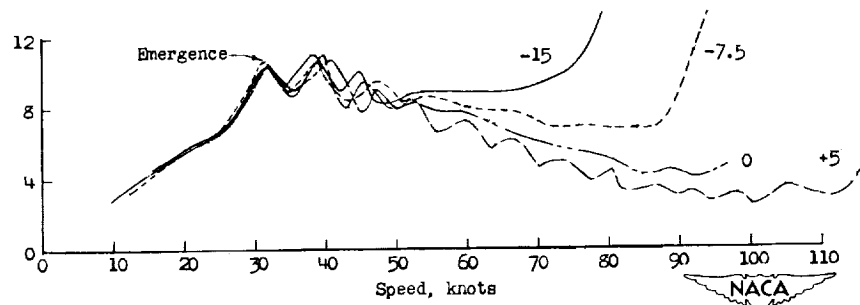
(d) Center-of-gravity location, 30 percent mean aerodynamic chord.

Figure 10.- Trim tracks. Gross load, 33,000 pounds; flap deflection, 20°;
rate of acceleration, 5.5 feet per second per second.
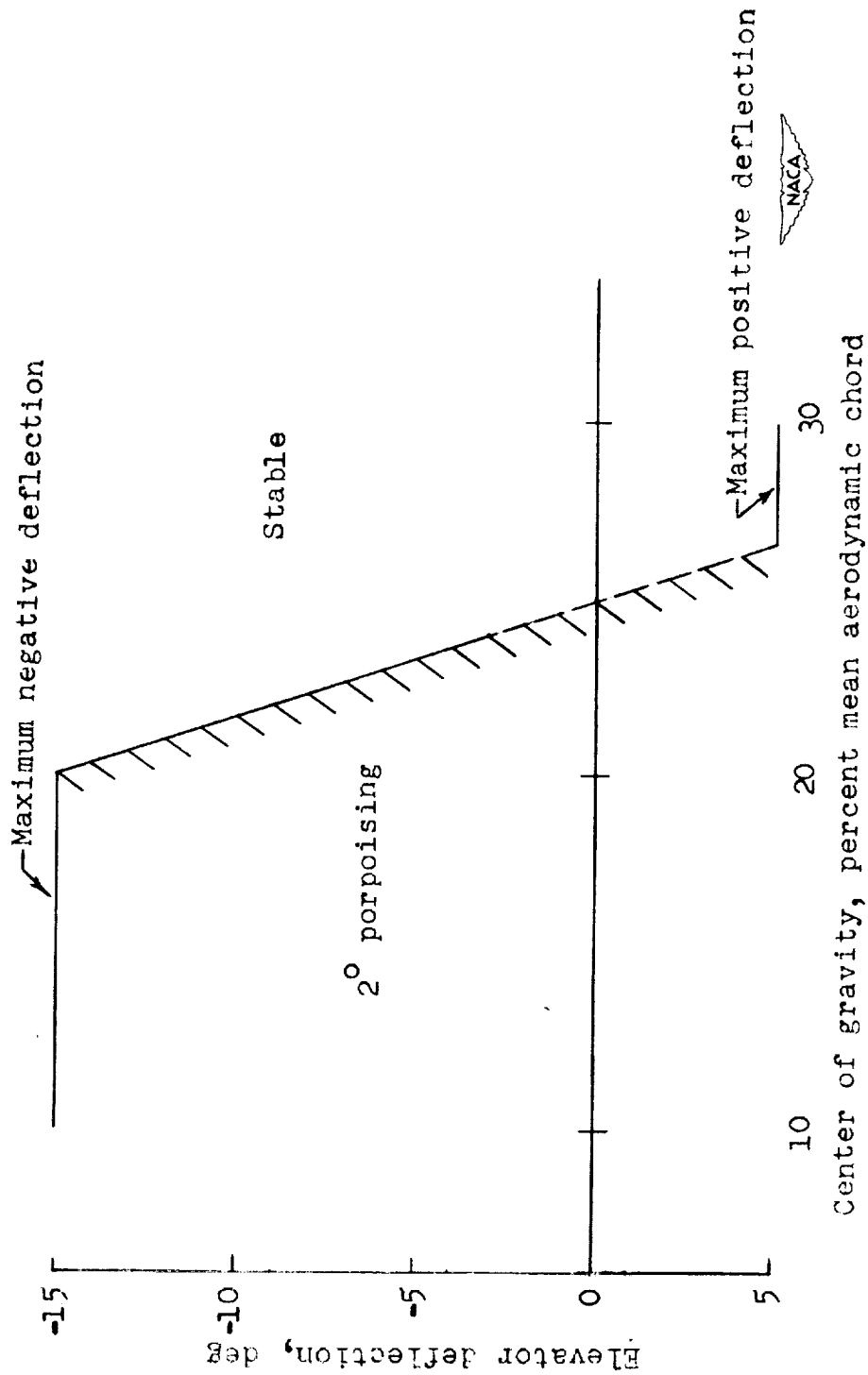
Figure 11.- Elevator limits for various center-of-gravity locations. Gross load, 33,000 pounds; flap deflection, 20°.
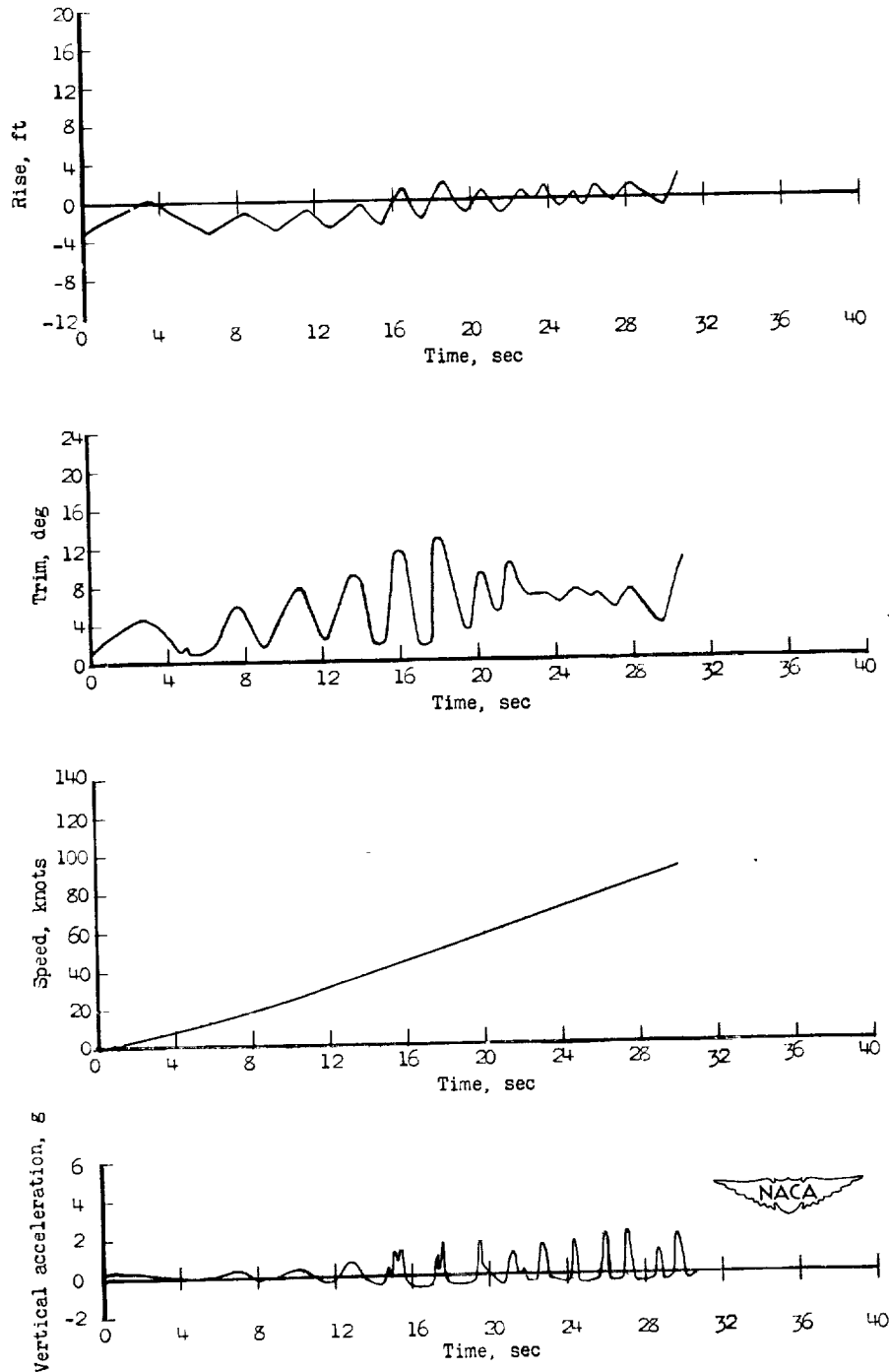
(a) Wave length, 243 feet; center-of-gravity location, 20 percent mean aerodynamic chord; rate of acceleration, 5.5 feet per second per second.

Figure 12.- Time histories of take-offs made in rough water. Gross load, 33,000 pounds; flap deflection, 20°; elevator deflection, -7.5°.
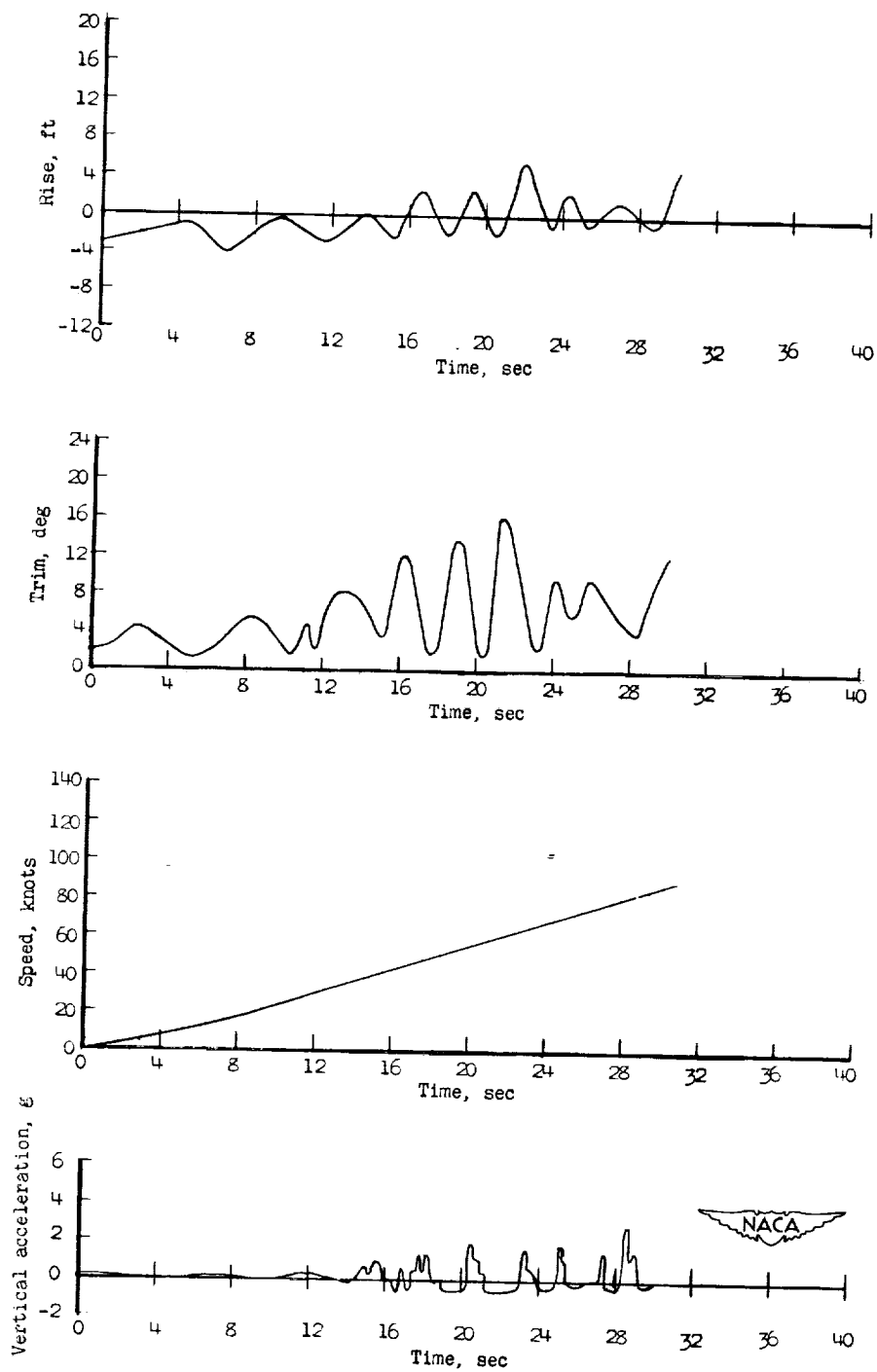
(b) Wave length, 324 feet; center-of-gravity location,
     20 percent mean aerodynamic chord; rate of acceleration,
     5.5 feet per second per second.

Figure 12.- Continued.
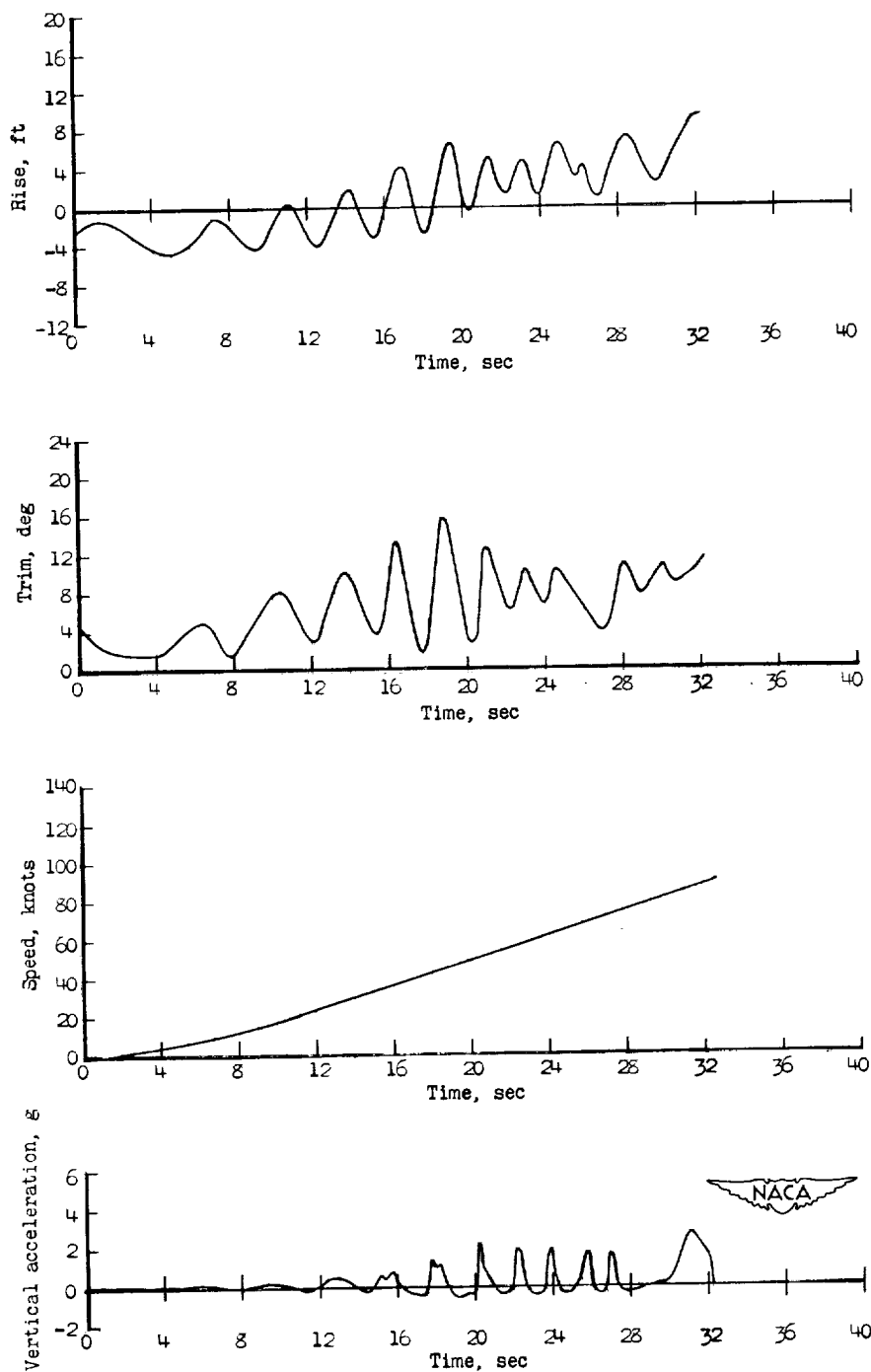
(c) Wave length, 243 feet; center-of-gravity location,
     30 percent mean aerodynamic chord; rate of acceleration,
     5.5 feet per second per second.

Figure 12.- Continued.
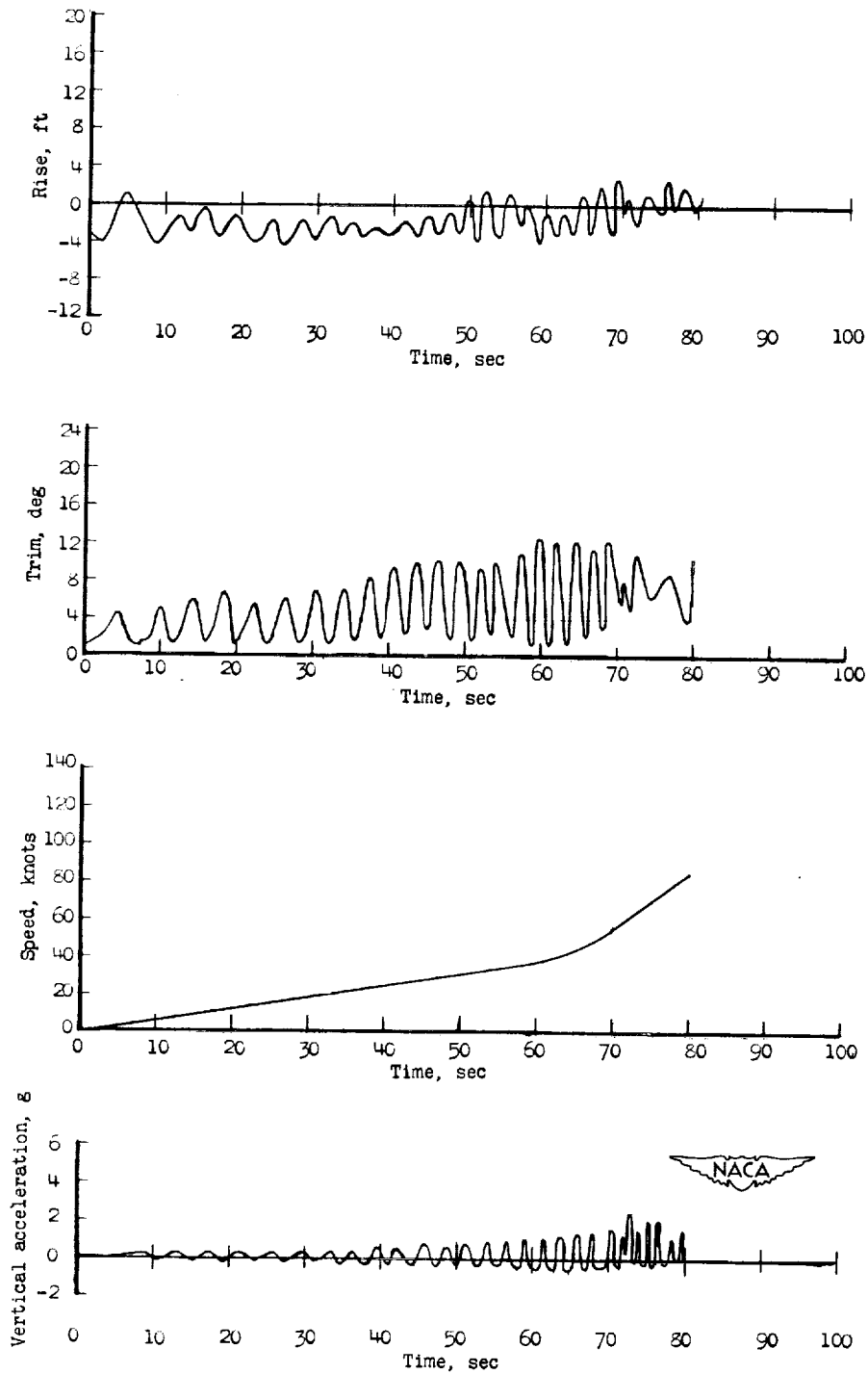
(d) Wave length, 243 feet; center-of-gravity location, 20 percent mean aerodynamic chord; rate of acceleration, 1.0 and 5.5 feet per second per second.

Figure 12.- Concluded.
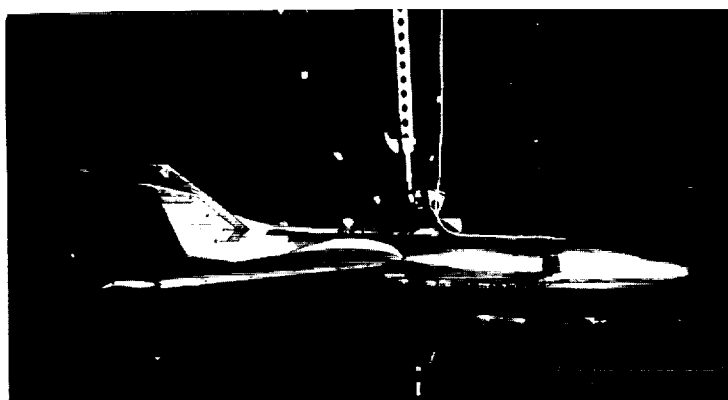
(a) Speed, 0 knots; trim, 2.1°.
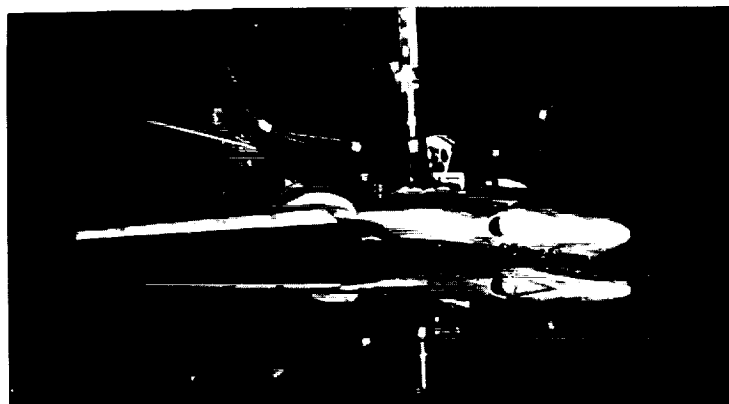
(b) Speed, 10.7 knots; trim, 2.3°.
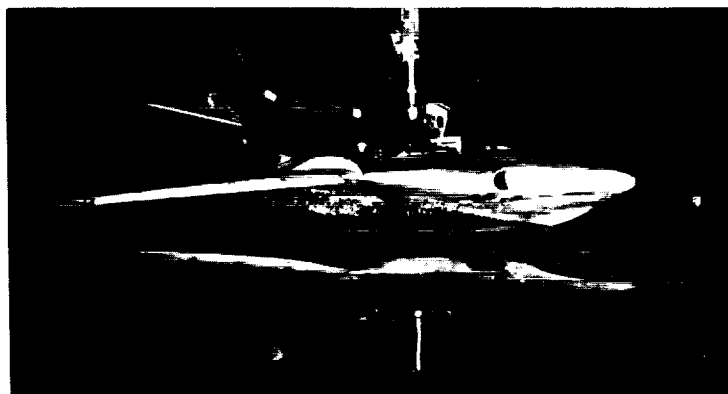
(c) Speed, 21.4 knots; trim, 5.5°.

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Figure 13.- Speed-lamp pictures during constant-speed runs in smooth
water. Center-of-gravity location, 20 percent mean aerodynamic
chord; elevator deflection, -7.5°; gross load, 33,000 pounds.
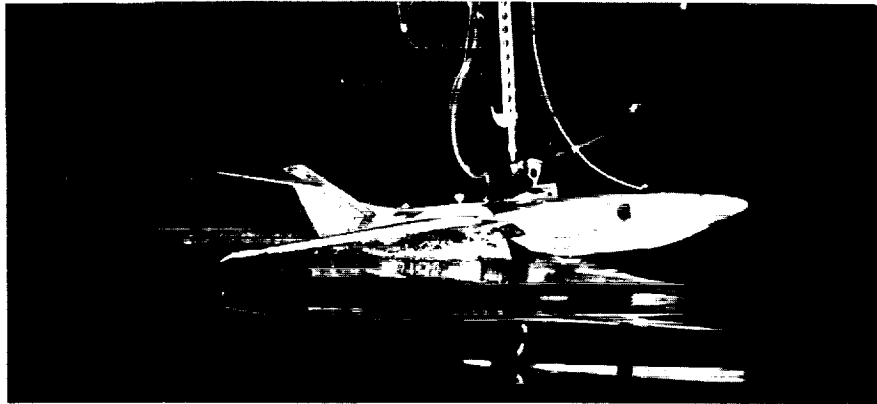
(d) Speed, 32.1 knots; trim, 7.5°.
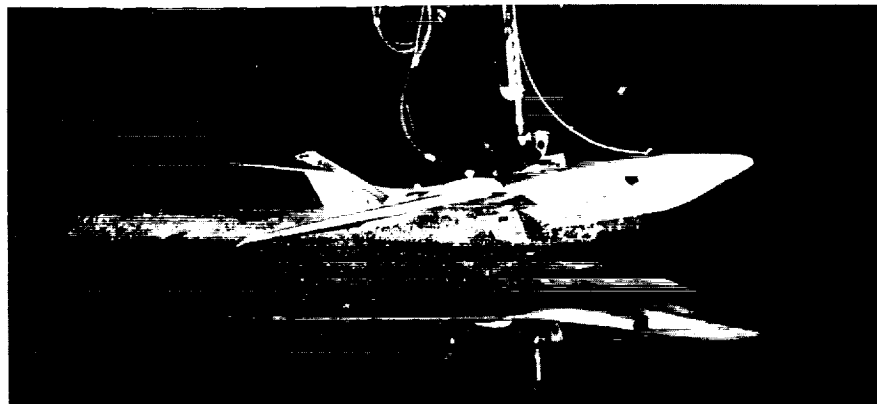
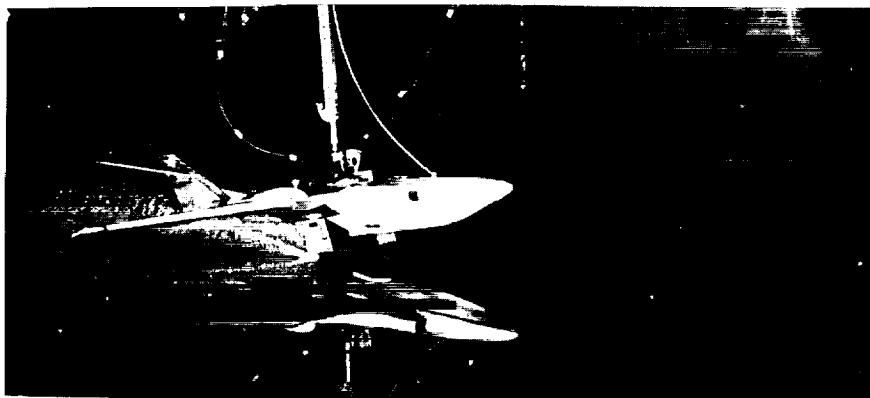(e) Speed, 42.8 knots; trim, 8.9°.
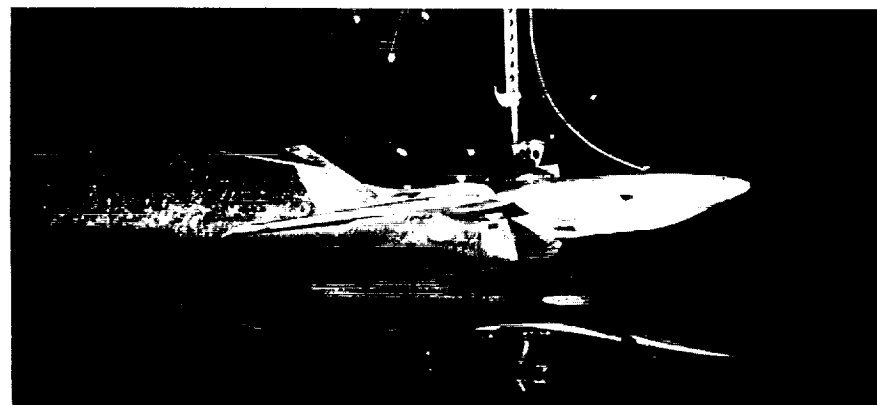
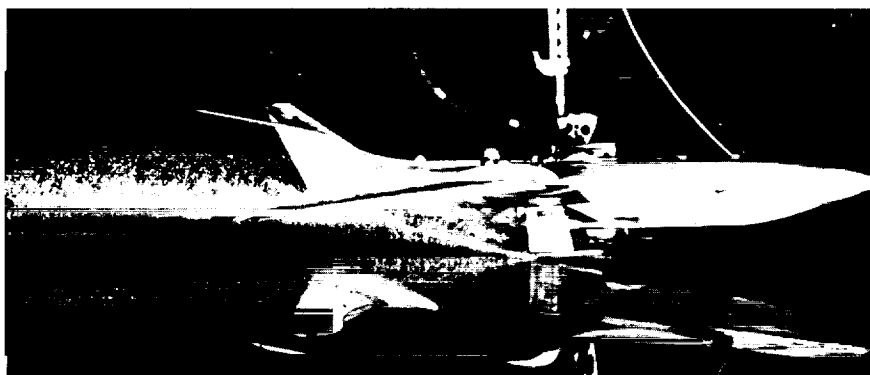(f) Speed, 53.5 knots; trim, 7.0°.

Figure 13.- Continued.

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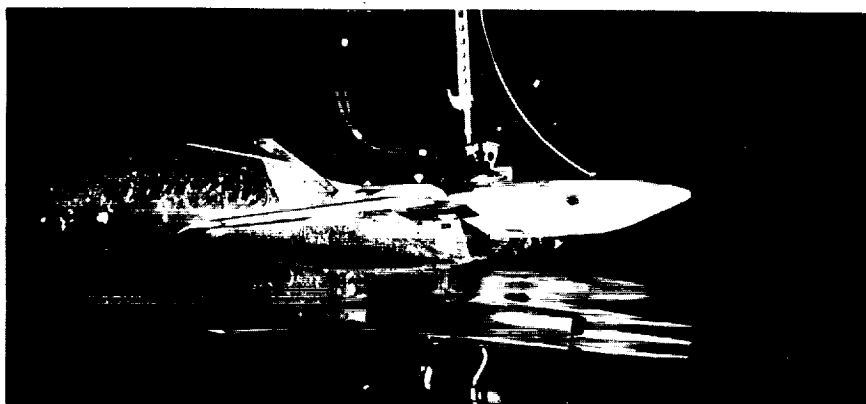
(g)   Speed, 64.2 knots; porpoising, 4° to 8°.

(h)   Speed, 74.9 knots; porpoising, 3.5° to 7°.

(j)   Speed, 85.6 knots; trim, 3.8°.

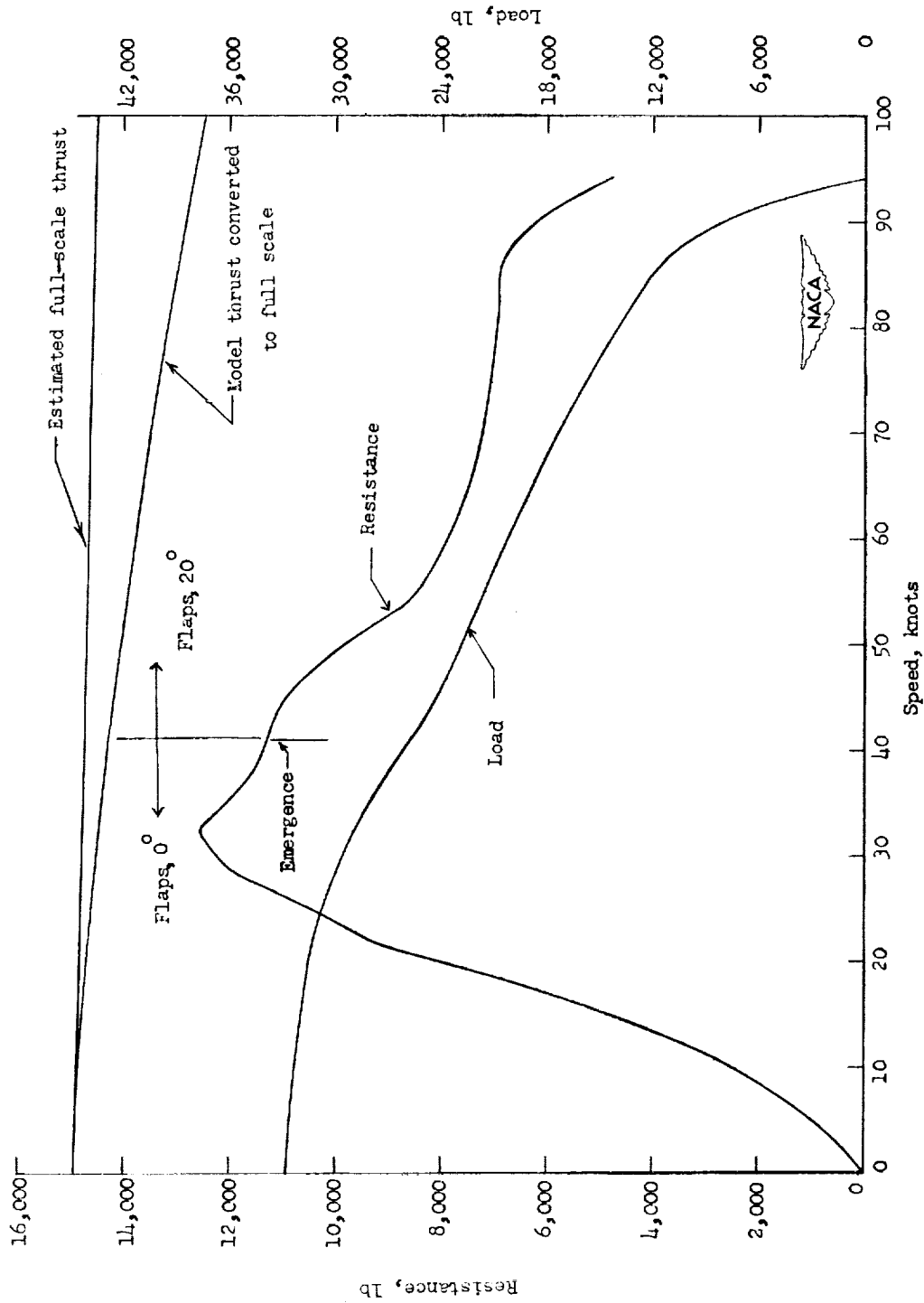Figure 13.- Concluded.

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Figure 14.- Resistance, load, and thrust for minimum stable resistance in trim range obtainable by use of the elevators. Full power; center of gravity, $0.20\bar{c}$.
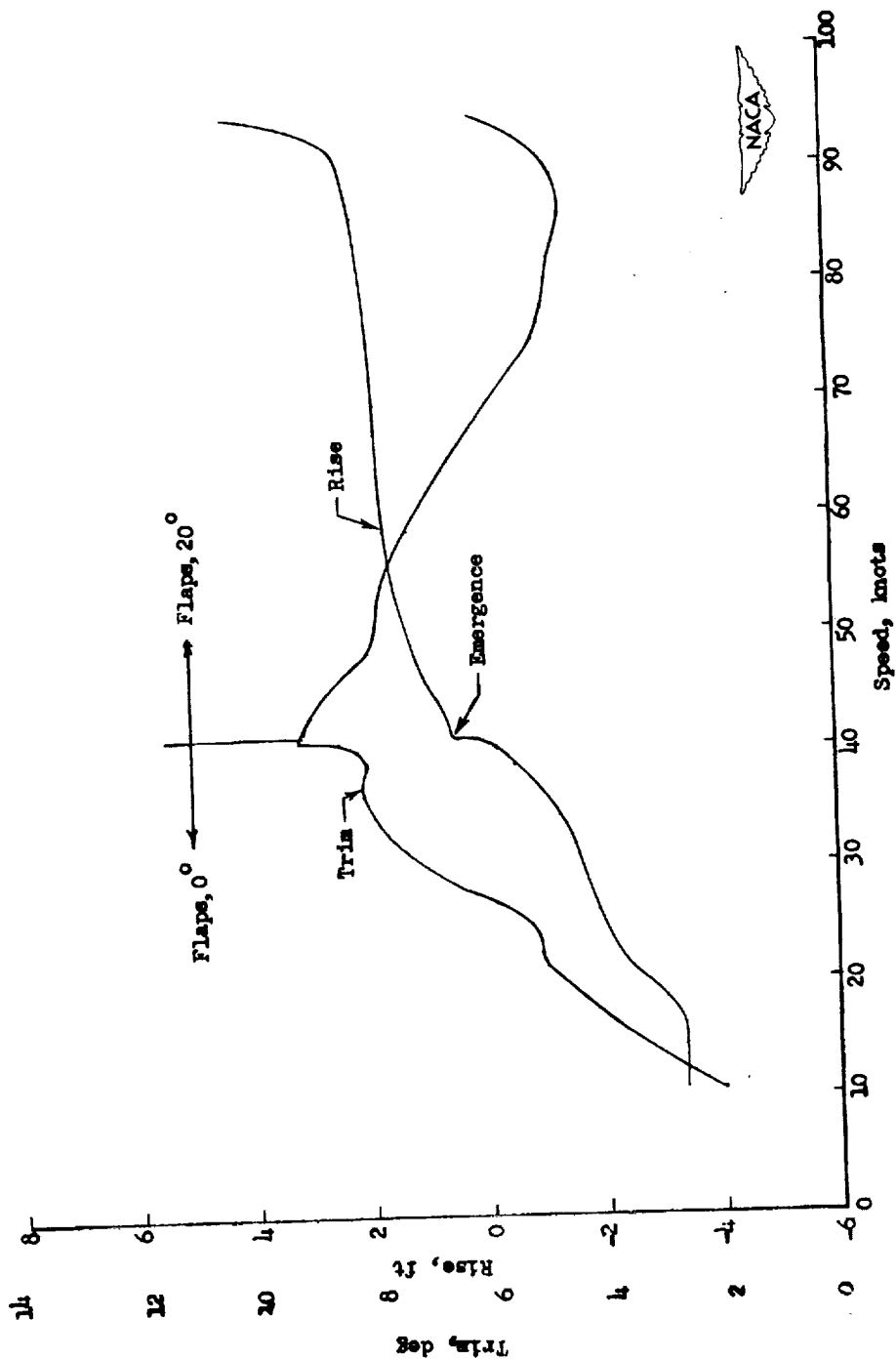
Figure 15.- Trim and rise for minimum stable resistance in trim range obtainable by use of the elevators. Full power; center of gravity, $0.20\bar{c}$.